# Secondary Forests on Anthropogenic Soils of the Middle Madeira River: Valuation, Local Knowledge, and Landscape Domestication in Brazilian Amazonia[1]

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**Secondary Forests on Anthropogenic Soils of the Middle Madeira River: Valuation, Local Knowledge, and Landscape Domestication in Brazilian Amazonia.** Anthropogenic forests and soils are widespread throughout Amazonia and are the product of the landscape domestication process carried out by Amazonian societies since pre-Colombian times. Areas of *Terra Preta de Índio* (TPI, Amazonian Dark Earths) are recognized by local rural residents and associated with specific forms of use and management of these soils and associated secondary forests. We used a quantitative approach to investigate how secondary forests on TPI are recognized and used by local residents along the middle Madeira River, Central Amazonia. Sixty-two residents were interviewed in three riverside communities and listed the ethnospecies and their uses in secondary forests on TPI and on non-anthropogenic soils (NAS). Local residents mentioned more ethnospecies on TPI (mean ± standard deviation: 19.5±8.9) than on NAS (17.4±8.5), and the use value of the environment to the informants (UVia) was higher on TPI (19±5.7) than on NAS (16.2±6.0). Eleven ethnospecies were classified as anthropogenic soil indicators, among which three intensively used palms are widely recognized as indicators of anthropogenic areas and two are domesticated to some degree. The intimate and lasting interactions between humans and TPI have favored the maintenance of secondary forests in these domesticated landscapes with a diverse assemblage of useful and domesticated species. Rural residents in Amazonia recognize these forests as an important source of food and other resources. The use, management, and traditional knowledge related to these domesticated landscapes may provide useful information for the understanding of Amazonian historical ecology and for the design of more efficient biodiversity management and conservation plans.

**Florestas secundárias sobre solos antrópicos do médio Rio Madeira: valoração, conhecimento local e domesticação da paisagem na Amazônia Brasileira.** Florestas e solos antrópicos são amplamente distribuídos na Amazônia e são resultado do processo de domesticação da paisagem pelas sociedades Amazônicas desde tempos pré-Colombianos. Áreas de Terra Preta de Índio (TPI) são reconhecidas por moradores locais e associadas com formas específicas de uso e manejo desses solos e das florestas secundárias associadas a eles. Utilizamos uma abordagem quantitativa para investigar como as florestas secundárias sobre TPI são conhecidas e utilizadas por moradores locais no médio Rio Madeira, Amazônia Central. Sessenta e dois moradores foram entrevistados em três comunidades ribeirinhas e listaram etnoespécies e os seus usos em florestas secundárias em TPI e em solos não-antrópicos (NAS). Os residentes locais mencionaram mais etnoespécies em TPI (média ± desvio padrão: 19,5±8,9) do que em NAS (17,4±8,5), e o valor de uso do ambiente para os informantes (UVia) foi maior em TPI (19±5,7) do que em NAS(16,2±6,0). Onze etnoespécies foram classificadas como indicadoras de solos antrópicos, entre as quais três palmeiras intensivamente utilizadas e amplamente reconhecidas como indicadoras de áreas

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antropogênicas, duas das quais domesticadas em algum grau. As interações íntimas e duradouras entre humanos e TPI nessas paisagens domesticadas favoreceram a manutenção de florestas secundárias com uma diversa assembléia de espécies úteis e domesticadas. Moradores locais na Amazônia reconhecem essas florestas como uma fonte importante de alimentos e de outros recursos. A utilização, manejo e o conhecimento tradicional relacionados a essas paisagens domesticadas podem fornecer informações úteis para o entendimento da ecologia histórica da Amazônia e para o desenvolvimento de estratégias mais eficientes de manejo e conservação da biodiversidade.

**Key Words:** Ethnobotany; Amazonian Dark Earths; traditional forest management; traditional knowledge; quantitative ethnobotany.

## Introduction

Secondary forests are increasingly recognized as an important source of resources for rural communities. In the Neotropics, local people often use secondary forests more intensively than primary forests (Chazdon and Coe 1999; Toledo et al. 1995; Toledo and Salick 2006; Voeks 1996). Numerous fast-growing trees in secondary forests are recognized for their value as timber (Finegan 1992; Wadsworth 1987), and the relative abundance of timber species is often higher in secondary forests than in old-growth forests (Chazdon and Coe 1999; Toledo et al. 1995; Toledo and Salick 2006). Secondary forests also contain a wide variety of useful and economically valuable non-timber forest products, including fruits and medicinal plants, and provide habitat for many game animals (Chambers and Leach 1989; Coomes et al. 2000; Corlett 1995; Voeks 1996), making them vital for food, economic security, and even sovereignty (Gavin 2004).

Throughout Brazilian Amazonia, anthropogenic soils that are the product of pre-Columbian indigenous activities are called *Terra Preta de Índio* (Amazonian Dark Earths, hereafter TPI; Woods and Denevan 2009). Most TPI patches are between 500 and 2,500 years old (Neves et al. 2003). TPI are widely distributed in Amazonia, occurring in patches that vary in area from a few (one or two) to tens or hundreds of hectares (Smith 1980). TPI patches are especially common in Brazilian Amazonia (Sombroek et al. 2002), but they also occur in Colombia, Peru, Venezuela, Bolivia and the Guianas (Andrade 1983; Eden et al. 1984). Together with alluvial soils, TPI are recognized as the most productive soils for agriculture in Amazonia (Hiraoka et al. 2003), and today TPI are frequently associated with specific and more intensive forms of agriculture (Fraser et al. 2009; Fraser and Clement 2008; German 2003a, b). However, the specific cultural and ecological processes that created these soils are still poorly understood and are the focus of an intense, multidisciplinary scientific effort (Woods and Denevan 2009).

Several ecological aspects of secondary succession on TPI are different from background soils (Clement et al. 2009; Junqueira et al. 2010), which are generally more acidic and poor in nutrients. Some qualitative and ethnographical studies have found that TPI areas in diverse stages of forest regrowth are recognized by traditional farmers through indicator plant species and by specific structural characteristics (lower canopies, denser understories, etc.), even when vegetation is dense (German 2003a, b; Moran 1981; Sombroek et al. 2002; Woods and McCann 1999). Recently, Junqueira et al. (2010) showed that secondary forests on TPI have different species composition and vegetation structure when compared with secondary forests on non-anthropogenic soils, and that these forests concentrate agrobiodiversity through the maintenance of a higher concentration of species with populations domesticated to some degree at the time of the European arrival in Amazonia (Clement 1999).

These characteristics that are specific to secondary forests on TPI may imply different forms and intensities of use of these forests by local people. However, no studies to date have addressed the utilization of secondary forests on anthropogenic soils. This type of data can improve the understanding of Amazonian historical ecology and reveal how recent inhabitants of Amazonia have transformed and adapted to landscapes that were domesticated in pre-Columbian times. Also, understanding the patterns of plant use by local people helps to identify environments that are more important as sources of plant resources or to detect eventual under/

overexploitation of species, and provides many other types of useful information for the design of more efficient biodiversity management and conservation plans (Galeano 2000; Phillips et al. 1994; Thomas et al. 2009). We use a quantitative ethnobotanical approach based on interviews with residents from riverside communities along the middle Madeira River, Brazilian Amazonia, to compare the usefulness of secondary forests on anthropogenic and non-anthropogenic soils, and to identify which secondary forest species are considered by local residents as TPI indicator species. Specifically, we tested the following hypotheses: 1) secondary forests on TPI have a higher Use Value than secondary forests on non-anthropogenic soils, and 2) some species are recognized locally as TPI indicators, among them useful species that contain populations domesticated to some degree.

## Methods

### Research Sites

Fieldwork was carried out in three riverside communities located in the municipality of Manicoré, on the middle Madeira River, Amazonas state, Brazil: Água Azul (5° 49' 57" S; 61° 33' 56" W), Barreira do Capanã (5° 50' 51" S; 61° 40' 11" W), and Terra Preta do Atininga (5° 38' 19" S; 61° 3' 6" W; Fig. 1). These communities are inhabited by *caboclos*, descendants of immigrants who arrived in the region from northeast of Brazil during the rubber boom in the beginning of the 20th century and intermarried with local indigenous people. About 42, 38, and 36 families live in Água Azul, Barreira do Capanã, and Terra Preta do Atininga, respectively. Major economic and subsistence activities include the extraction of Brazil nut (*Bertholletia excelsa* Bonpl.) and rubber (*Hevea brasiliensis* (Willd. ex A. Juss) Mull. Arg.), and the cultivation of manioc (*Manihot esculenta* Crantz). All three communities manage mosaics of home-gardens, swiddens, and secondary forests in various successional stages, part of which are located on patches of TPI.

### Interviews

Data collection was based on interviews with 62 local residents (22 at Água Azul, 20 at Barreira do Capanã, and 20 at Terra Preta do Atininga), chosen in a way that people of both genders and a wide range of ages were interviewed. However, we avoided interviewing more than one person per family, which ended up biasing our sample to the male residents, given the local habit of the man (or the "family chief") hosting the researcher. We interviewed a total of 54 males (87%) and eight

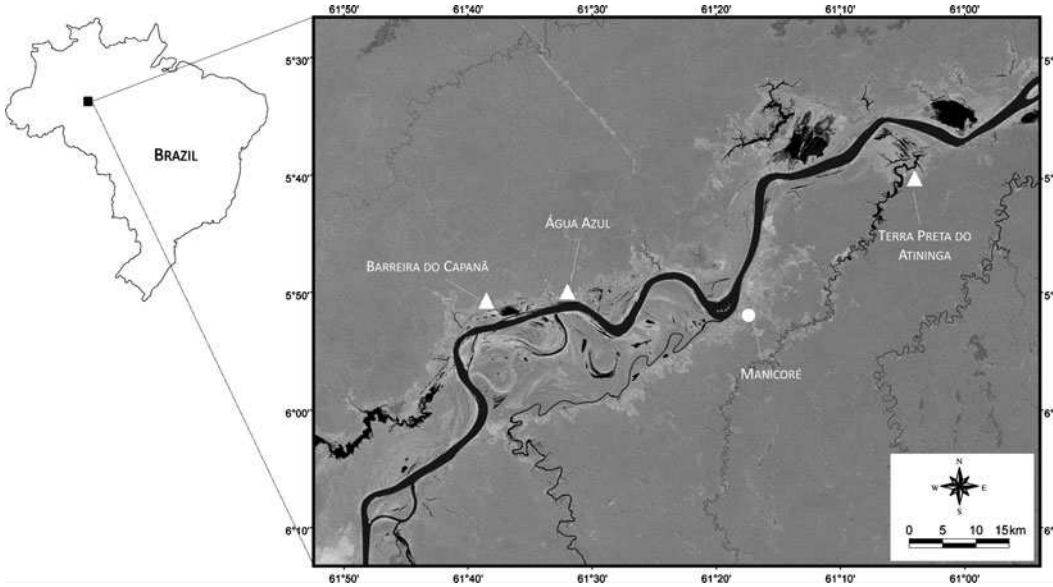


**Fig. 1.** Location of study sites. White triangles represent the three communities where the interviews were done, and the white circle indicates the town of Manicoré, located along the middle Madeira River, Amazonas, Brazil.

females (13%). For the males, the age of the interviewee varied between 18 and 77 years (mean ± standard deviation: 46.3±15.7); for the females, the age varied between 33 and 68 years (48.2±13.3). Also, the degree of interaction among local residents and anthropogenic soils may vary considerably within each community, since there are some families that cultivate and live on top of anthropogenic soils, while others are much less familiar with these environments. In order to avoid this bias on our data, we interviewed local residents who lived along the whole community, and we tried to interview about the same number of residents living on top of or outside the patches of anthropogenic soils.

The interview consisted of *free listings* (Bernard 1988), stimulating the interviewee to provide a list of the plants he/she knew that occurred in secondary forests (known locally as *capoeiras*) on anthropogenic soils (TPI) and on non-anthropogenic soils (hereafter NAS). We asked the following questions: "What plants do you know that occur in *capoeiras* on *terra preta*?" and "What plants do you know that occur in *capoeiras* on other soils?" Once the interviewee stopped naming plants, he/she was asked if each plant cited had any known use and, when affirmative, what was this use (or uses). The uses cited were classified in use categories, most of which have been employed in other ethnobotanical studies (e.g., Galeano 2000; Phillips and Gentry 1993a, b; Phillips et al. 1994; Prance et al. 1987): Firewood, food, construction, "hunting/fishing-wait" (plants that attract game animals and are actively sought for hunting, or plants that attract fish when occurring on river margins), "opportunistic-hunting/fishing" (plants that attract game or fish but that are not actively sought for hunting or fishing), medicine (also includes "magical", ritual, and cosmetic uses), other technology (a wide category, including uses related to the construction of tools, handicrafts, toys, fish-baits etc.), commerce/trade, and "household animals" (plants used for feeding domestic animals).

The access to traditional knowledge is governed by federal legislation in Brazil (Provisional Measure 2186–16, 2001), requiring a previous agreement with the communities and the informants before the study begins. The authorization for this study was granted by the Genetic Heritage Management Council (CGEN, Process 02000.001202/207-89) and by the Research Ethics Committee of the National Institute of Amazonian Research (CEP-INPA, Process 079/2006).

## Data Analysis

Based on the free listings, we calculated the Use Value (UV) of each plant cited (hereafter *ethnospecies*), using a modification of the Phillips and Gentry (1993a, b) Use Value algorithm as proposed by Rossato et al. (1999) and Fraser and Junqueira (2010):

$$UVis = \Sigma Uis$$

where UVis is the UV of ethnospecies $s$ for informant $i$ and Uis is the number of uses mentioned by informant $i$ for species $s$ during the interview. The total UV for a given species (UVs) is therefore calculated through the formula:

$$UVs = \Sigma UVis/ns$$

where ns is the total number of informants interviewed.

In order to compare TPI and NAS with respect to the utilization of the secondary forests, we calculated the UV of each environment $a$ (TPI and NAS) for each informant $i$ (UVia) by summing the UVs of all the ethnospecies cited by informant $i$ in each environment $a$. The number of ethnospecies cited *per* informant and the UVia values were compared between TPI and NAS using paired $t$-tests.

It is important to mention, however, that the use of natural resources takes place within specific cultural contexts (Albuquerque and Lucena 2005), and that the Phillips and Gentry (1993a, b) Use Value technique and its derivations have limitations related to interpretations regarding the actual use of natural resources that only recently have been critically examined (Lucena et al. 2007). The Use-Value index, since it is based on the memory of the informants about the names and uses of plants, reveals *cognitive saliency of use*, which does not necessarily correspond to the actual utilization of the species (Lucena et al. 2007; Torre-Cuadros and Islebe 2003). On the other hand, the use of an index such as the UV permits clear hypothesis testing and offers an objective approach to the usefulness of species to the informants, among several other advantages (Phillips et al. 1994). Also, UVs is correlated with the frequency of citation of

the species (i.e., species that are mentioned by many informants have high UVs), and high values of this index represent, therefore, a shared knowledge about the usefulness of a given species, suggesting actual use.

To identify which species are recognized by local residents as associated with TPI, we used the Indicator Species Analysis (Dufrene and Legendre 1997). This analysis, originally developed for the analysis of natural biological communities, combines information on species abundance in a given group and the "loyalty" of occurrence of a species in a given group (i.e., species that are frequent in a given group but rarely occur in another). To adapt this method to interview data, we used the abundance of citations of a given ethnospecies in TPI or NAS and the loyalty of the cited ethnospecies to each one of these environments. The analysis generates Indicator Values (IV) of each species in each group (TPI and NAS); its statistical significance was tested with the Monte Carlo technique, with 10,000 randomizations. The Indicator Species Analysis was done with the software PC-ORD (McCune and Mefford 1999), and all other analyses were done with SYSTAT 10.2 (Wilkinson 2002).

For correspondence between local and scientific names, the plant names cited during the interviews were compared with the database of Junqueira et al. (2010), who sampled plots of secondary forests on TPI and on NAS in the same region and obtained local names for the species from their key informants. Occasionally, we also conducted field interviews (or "walk in the woods," following Alexiades [1996] and Cunningham [2001]) with at least three "key informants" in each community (informants who showed a more detailed knowledge about plants and were recognized as "specialists" by other members of the community), during which they were taken on "tours" in secondary forest areas, providing local names for some individuals previously identified by the researchers. Although there is not a one-to-one correspondence between folk taxa and scientific species (Berlin 1992; Berlin et al. 1974), the degree of consensus among informants regarding the association of a given plant to a name tends to be higher among plants that are more frequently mentioned (which also tends to be the plants with the highest Use Value). By focusing on these commonly mentioned plants, therefore, the overall impact of informant variation is minimized (Abraão et al. 2008).

## Results and Discussion

### Usefulness of Secondary Forests on TPI and NAS

During the 62 interviews, 367 ethnospecies were cited, for which 4,327 uses were mentioned. The number of ethnospecies cited per informant varied between 4 and 47 on TPI (mean ± standard deviation: 19.5±8.9) and between 4 and 39 on NAS (17.4±8.5), and was significantly higher on TPI than on NAS (d.f.=61; t=–2.571; p=0.013; Fig. 2a). It is important to mention that these results are not biased by any difference between TPI and NAS regarding the species richness of secondary forests, since there seems to be no difference between these environments regarding species richness (Junqueira et al. 2010). The free listing technique is used to elucidate the elements or members of a given cultural domain (Borgatti 1999), and the number of items cited reflects the familiarity of the informant with this domain (i.e., "how well" the informant knows the cultural domain; Gatewood 1984). Because the number of items cited was higher on anthropogenic than on non-anthropogenic soils, it indicates that informants are more familiarized with the species of secondary forests on this soil than on non-anthropogenic soils. Also, 92.1 % of all ethnospecies cited had at least one use, which suggests that this "familiarization" may also reflect a greater usefulness of secondary forests on anthropogenic soils than on non-anthropogenic soils.

The use value of the environment to the informant (UVia) allows a more comprehensive examination of the relative usefulness of a given environment, since it takes into consideration not only the number of ethnospecies cited but also the *number of uses* cited for each ethnospecies. The UVia on TPI varied between 8.3 and 31.6 (mean ± standard deviation: 19.0±5.7), and on NAS varied between 2.9 and 28.9 (16.1±6.0), and was significantly higher on TPI than on NAS (d.f.=61; t=–4.949; p<0.001; Fig. 2b). The results obtained for UVia, therefore, indicate that secondary forests on TPI are more useful for local residents than secondary forests on NAS.

### Use Categories

On both soils, the use categories *medicine*, *other technology*, *construction*, and *food* contributed most to the total use value (Fig. 3), although in

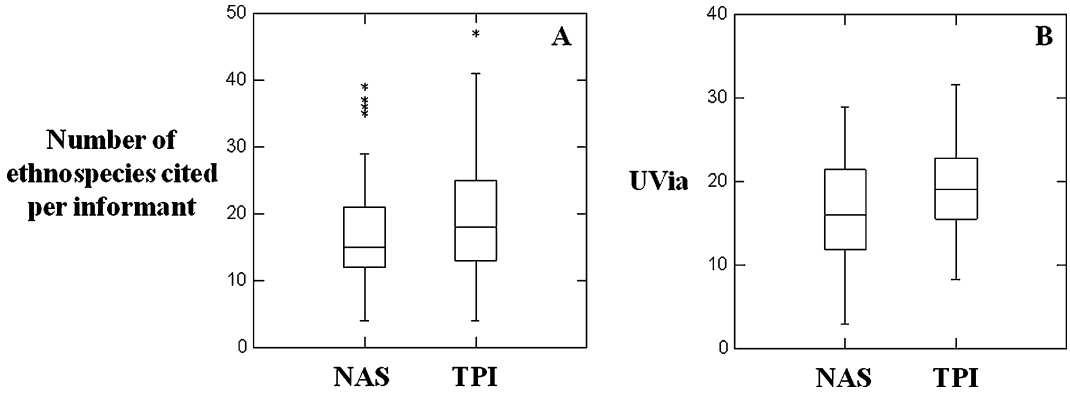


**Fig. 2.** Box plots showing comparisons between anthropogenic soils (TPI) and non-anthropogenic soils (NAS) with respect to (**a**) the number of ethnospecies cited per informant and (**b**) the use value of the environment to the informant (UVia; n=62) in three communities along the middle Madeira River, Amazonas, Brazil. The boxes indicate data between the third and fourth quartiles (interquartile interval), and the transversal lines inside each box show the median of each sample. Vertical lines outside the boxes are values up to 1.5 times the range of the box, and the asterisks indicate values between 1.5 and 3 times the range of the box.

slightly different orders of importance. Other ethnobotanical inventories in secondary forests also demonstrated that these environments have a high density of individuals and species used for these purposes (Chazdon and Coe 1999; Toledo and Salick 2006).

Large numbers of ethnospecies were cited both on anthropogenic and non-anthropogenic soils, even in the use categories that least contributed to the total UV. For example, the use category *household animals* (plants that are collected to feed domestic animals), which was the use category that least contributed to total UV in both environments, 25 ethnospecies were cited on TPI (8.7 % of the total cited in this environment) and 15 ethnospecies were cited on NAS (5.4 %). This suggests that local residents recognize these environments as a diversified source of useful plant

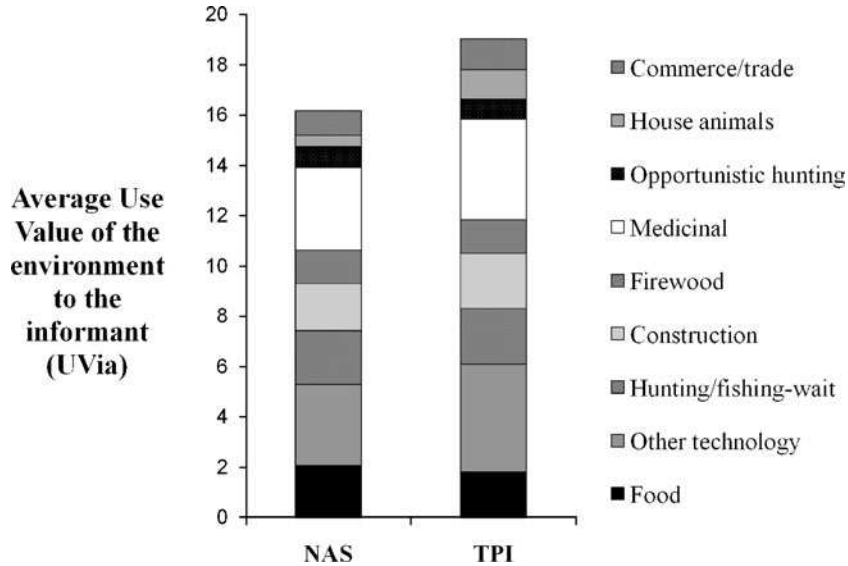


**Fig. 3.** Comparison between secondary forests on anthropogenic soils (TPI) and on non-anthropogenic soils (NAS) with respect to the average Use Value of the environment to the informant (UVia) and relative contribution of the use categories to the total UVia (n=62) in three communities along the middle Madeira River, Amazonas, Brazil.

species and that secondary forests on non-anthropogenic soils, although not as highly valued than secondary forests on anthropogenic soils, are also an important source of resources for local residents.

TPI had UVia values significantly higher than NAS in the use categories *food* (d.f.=61; t=−9.100; p<0.001), *other technology* (d.f.=61; t=−4.831; p<0.001), *hunting/fishing-wait* (d.f.=61; t=−3.913; p<0.001), *opportunistic hunting/fishing* (d.f.=61; t=−5.084; p<0.001), and *household animals* (d.f.=61; t=−13.281; p<0.001). It is clear therefore that secondary forests on anthropogenic soils are important for the food security of traditional populations, since numerous species associated with these soils provide, directly or indirectly, an important nutritional component of a diet based principally on carbohydrates, which is typical of Amazonian populations (e.g., Moran 1993; Murrieta et al. 1999).

Secondary forests on NAS had UVia significantly higher than on TPI only for the use category *firewood* (d.f.=61; t=−2.023; p=0.047). Firewood is a crucial resource considering that all families use firewood on a daily basis in their kitchens and in ovens for roasting manioc flour. However, although some ethnospecies cited are actively sought and valued for this purpose, it is a less specific form of use, since one species can be substituted by another much more easily than a species used for medicinal purposes, for example. Also, the extraction of firewood frequently causes the death of the tree and may cause significant changes in the population structure of the species (Tabuti et al. 2003), and therefore many ethnospecies that are used for other purposes are likely avoided. This could explain the lower use value of anthropogenic soils in this use category; since they are more used for other purposes, it is possible that secondary forests on non-anthropogenic soils are preferred for firewood extraction. The high use value of NAS in this category was also probably highly influenced by the ethnospecies "sapateiro" (which corresponds to several species of the genus *Miconia*), which is the fourth ethnospecies with the highest use value in the firewood category and is one of the indicator ethnospecies of NAS.

## Indicator Species

The Indicator Species Analysis found that 11 ethnospecies are TPI indicator species and two ethnospecies are NAS indicator species (Table 1). Among the ethnospecies considered by local residents as TPI indicators, three of them are palms: *caiaué* (*Elaeis oleifera* (Kunth.) Cortés), *urucuri* (*Attalea* cf. *phalerata* Mart. ex Spreng), and *murumuru* (*Astrocaryum murumuru* Mart.) (two of them—*caiaué* and *murumuru*—with incipiently domesticated populations; Clement 1999). Palms are the most important group of plants for traditional populations throughout Amazonia (Anderson 1977; Balick 1986; Campos and Ehringhaus 2003; Kahn and de Granville 1992). Our results support this, since seven among the 20 ethnospecies with the highest UVs are palms (Appendix 1). Also, palms are among the most noticed indicators on archaeological sites (Balée 1989), and archaeological evidence shows that the use of palms was already widespread 9,000 years ago (Morcote-Ríos and Bernal 2001). Several studies have shown that *caiaué* has a strict association with TPI (Andrade 1983; Balée 1989; Barcelos 1986; Junqueira et al. 2010; McCann 2003). *Urucuri* has been found strictly associated with TPI at some sites along the Madeira and Tocantins Rivers (Eletronorte 1992). Regarding *murumuru*, our results agree with McCann (2003), who reported that on the lower Negro River this is a species that occurs mainly on floodplains but also on anthropogenic soils.

Among the TPI indicators, all ethnospecies are useful, but apart from the three palms and *taperebá* (*Spondias mombin* L., which is also a species with semi-domesticated populations; Clement 1999), they all show a low use value (Table 1). Most of them are shrubs (*marmeleiro [Acalypha brasiliensis* Müll. Arg.], *pau-de-muquém* [species is indetermined], *batatão* [species is indetermined]) or treelets (*mata-pasto* [*Senna alata* L.], *jurubeba* [*Solanum* sp.]). Although these species are occasionally used for different purposes, the main reason why they are recognized as TPI indicator species is their strong association with the initial phases of secondary succession on abandoned TPI agricultural areas. On the other hand, both ethnospecies considered NAS indicators (*sapateiro* [*Miconia* spp.] and *cedrinho* [*Cedrela* sp. and *Tapirira guianensis* Aubl.]) have high use values (Table 1) and are among the 20 ethnospecies with the highest use values (Appendix 1). The usefulness of these ethnospecies most likely has a strong influence on their recognition as NAS indicator species.

Five of the ethnospecies recognized by local residents as indicator species of secondary forests on TPI correspond to botanical species that were also identified as indicator species by Junqueira et al. (2010), based strictly on ecological data:

TABLE 1. ETHNOSPECIES INDICATORS OF SECONDARY FORESTS ON ANTHROPOGENIC SOILS (TPI) AND NON-ANTHROPOGENIC SOILS (NAS) BASED ON DATA FROM INTERVIEWS WITH 62 LOCAL RESIDENTS OF THREE COMMUNITIES ALONG THE MIDDLE MADEIRA RIVER, AMAZONAS, BRAZIL.

| | | | | | IV[c] from randomized groups | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Soil | Common name | Species[a] | Family[b] | IV[c] observed | average | SD[d] | p[e] | UVs[f] | DD[g] |
| TPI | Caiaué | *Elaeis oleifera* (Kunth.) Cortés | Arecaceae | 69.7 | 23.6 | 2.97 | <0.001 | 2.339 | id |
| | Urucuri | *Attalea* cf. *phalerata* Mart. ex Spreng | Arecaceae | 60.2 | 30.8 | 2.96 | <0.001 | 3.065 | nd |
| | Murumuru | *Astrocaryum murumuru* Mart. | Arecaceae | 44.9 | 21.5 | 3 | <0.001 | 1.274 | id |
| | Oicima | *Apeiba tibourbou* Aubl. | Malvaceae | 37.2 | 13.3 | 2.58 | <0.001 | 0.323 | nd |
| | Marmeleiro | *Acalypha brasiliensis* Müll. Arg. | Euphorbiaceae | 29 | 10.1 | 2.44 | <0.001 | 0.226 | nd |
| | Mata-pasto | *Senna alata* L. | Fabaceae - Caes. | 22.6 | 8.3 | 2.29 | <0.001 | 0.129 | nd |
| | Samaúma | *Ceiba pentandra* (L.) Gaertn. | Malvaceae | 14.7 | 6.9 | 1.95 | 0.008 | 0.21 | nd |
| | Batatão | Indetermined | Indetermined | 14.5 | 5.9 | 1.82 | 0.003 | 0.21 | nd |
| | Taperebá | *Spondias mombin* L. | Anacardiaceae | 13.9 | 8.2 | 2.25 | 0.041 | 0.645 | sd |
| | Jurubeba | *Solanum* sp. | Solanaceae | 11.5 | 5.9 | 1.8 | 0.031 | 0.032 | nd |
| | Pau-de-muquém | Indetermined | Indetermined | 9.7 | 4.3 | 1.72 | 0.027 | 0.113 | nd |
| NAS | Cedrinho | *Cedrela* sp. | Meliaceae | 31.6 | 23.5 | 2.93 | 0.025 | 0.834 | nd |
| | | *Tapirira guianensis* Aubl. | Anacardiaceae | | | | | | nd |
| | Sapateiro | *Miconia* spp. | Melastomataceae | 25.8 | 18.1 | 2.94 | 0.029 | 0.871 | nd |

[a] Most likely botanical species to which the common name refers; [b] Fabaceae-Caes. refers to the subfamily Caesalpinoideae *sensu* APG II (2003); [c] Indicator Value; [d] Standard deviation; [e] Probability of one randomized trial to generate an IV equal to or higher than the observed IV; [f] Use Value of the ethnospecies; [g] Degree of domestication sensu Clement (1999): id - incipiently domesticated; sd - semi-domesticated; nd - non-domesticated

*Caiaué, murumuru, oicima* (*Apeiba tibourbou* Aubl.), *taperebá*, and *urucuri*. Besides showing that the interview method is efficient for identifying indicator species, these results also demonstrate a close correspondence between traditional knowledge and ecological science related to secondary forests on anthropogenic soils.

### Landscape Domestication and the Concentration of Useful Species in TPI

The usefulness of a given environment is directly related to the concentration of useful species in it. The concentration of useful species in some anthropogenic areas (such as secondary forests) is a result of the process of *landscape domestication*, through which the "manipulation of the landscape by humans results in changes in landscape ecology and in the demography of plant and animal populations, resulting in a more productive and favorable landscape for humans" (Clement 1999). Domesticated landscapes with concentrations of useful species occur in a wide variety of ecosystems in Amazonia (Erickson 2008) and Mesoamerica (Campbell et al. 2006; Ford and Nigh 2009).

Anthropogenic soils are a clear product of landscape domestication (Erickson 2008). They result from pre-Columbian permanent occupation patterns and intensive cultivation practices that caused profound transformations in the biotic environment through practices such as burning, weeding, fertilizing, etc., which in turn favored the growth of some food plants and other useful species (Arroyo-Kalin et al. 2009; Clement et al. 2003; Junqueira et al. 2010; Neves et al. 2003; Woods and Denevan 2009). Many of these species may persist for a long time on these sites and contribute to the seed bank of adjacent areas. In fact, some oral histories we heard during interviews with the older informants pointed consistently to a high concentration of useful species on the patches of anthropogenic soils (especially fruit trees), even before the communities were established at the site between 100 to 120 years ago. These profound modifications in the soils and forests caused by pre-Columbian people, together with recent practices of secondary forest use and management, have led to the formation of secondary forests with a diverse assemblage of useful species. We argue, therefore, that secondary forests on anthropogenic soils are highly valued by local residents because of the greater intensity of landscape domestication under which these environments have been since pre-Columbian societies began to manage them.

## Conclusions

Our hypotheses that secondary forests on anthropogenic soils would show a higher Use Value than secondary forests on non-anthropogenic soils and that local residents would recognize useful species with domesticated populations as anthropogenic soil indicators were both corroborated. This implies that in areas where the soil and vegetation have been substantially modified by long-term human activity, the resulting secondary forests are more useful to traditional populations than secondary forests in areas where the process of landscape domestication has been less intensive. Additionally, we have shown that traditional populations along the middle Madeira River recognize secondary forests on anthropogenic soils as an important source of non-timber forest products, and that the concentration of useful species in these environments is a noticeable feature for local people.

Recognizing the role of secondary forests as important resources raises the issue of the potential of these forests for sustainable management. Secondary forests on anthropogenic soils are a clear example that traditional practices of soil and forest management may result in highly productive environments. Traditional knowledge about the use and management of soils and secondary forests provides important insights for the development of strategies of sustainable natural resource management in Amazonia. If non-timber forest products could be extracted in a sustainable way from managed secondary forests, the protection of mature forests could be a more attainable conservation goal (Budowsky 1988).

Our results have important implications for our understanding of Amazonian historical ecology as well. Until recently, Amazonia was viewed as a pristine environment, little changed by the activity of the small, simple societies that inhabited it. This paradigm is changing in the face of numerous studies from several disciplines showing that some regions of Amazonia were densely inhabited by large complex indigenous societies that promoted deep transformations in the landscape (Heckenberger

2003, 2007; Mann 2005). Today, secondary forests on anthropogenic soils are complex environments that differ in floristic and structural characteristics from other secondary forests and concentrate agrobiodiversity (Junqueira et al. 2010). We have shown that the current local residents highly value secondary forests on anthropogenic soils, having incorporated these domesticated landscapes into their knowledge and practices. Although part of these characteristics may result from current practices of use and management, part of them is certainly an inheritance from pre-Columbian activities on these anthropogenic soils. Hence, we can affirm that pre-Columbian modifications in the soil and forests persist for a long time and influence current patterns of resource use and management.

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## Appendix

APPENDIX 1. LIST OF THE 20 SPECIES WITH THE HIGHEST USE-VALUE (UVs) CITED BY LOCAL RESIDENTS IN SECONDARY FORESTS ON ANTHROPOGENIC SOILS (TPI) AND NON-ANTHROPOGENIC SOILS (NAS) ALONG THE MIDDLE MADEIRA RIVER, AMAZONAS, BRAZIL.

| | | | | | | | $UV_s$[f] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common name | Species[a] | Family[b] | ni[c] | niTPI[d] | niNAS[d] | nu[e] | fir | fod | cst | hwt | med | tec | com | han | oph | $UV_s$[g] total |
| Castanheira | *Bertholletia excelsa* Bonpl. | Lecythidaceae | 27 | 23 | 24 | 257 | 0.145 | 1.274 | 0.484 | 0.048 | 0.565 | 1.161 | 0.355 | 0.000 | 0.113 | 4.145 |
| Tucumã | *Astrocaryum aculeatum* Meyer | Arecaceae | 56 | 49 | 53 | 240 | 0.016 | 1.194 | 0.016 | 0.839 | 0.032 | 1.129 | 0.516 | 0.097 | 0.032 | 3.871 |
| Babaçu | *Attalea* cf. *speciosa* (Barb. Rodr.) Wess. Boer | Arecaceae | 49 | 44 | 41 | 219 | 0.000 | 0.750 | 0.718 | 0.548 | 0.048 | 1.113 | 0.032 | 0.226 | 0.097 | 3.532 |
| Urucuri | *Attalea* cf. *phalerata* Mart. ex Spreng | Arecaceae | 50 | 50 | 17 | 190 | 0.000 | 0.935 | 0.355 | 0.597 | 0.000 | 0.871 | 0.000 | 0.194 | 0.113 | 3.065 |
| Caiaué | *Elaeis oleifera* (Kunth.) Cortés | Arecaceae | 46 | 46 | 3 | 145 | 0.016 | 0.710 | 0.194 | 0.145 | 0.065 | 0.403 | 0.016 | 0.516 | 0.274 | 2.339 |
| Açaí | *Euterpe precatoria* Mart. | Arecaceae | 25 | 21 | 19 | 115 | 0.032 | 0.565 | 0.435 | 0.048 | 0.048 | 0.065 | 0.194 | 0.145 | 0.323 | 1.855 |
| Ingá-xixica | *Inga heterophylla* Willd.<br>*Inga lateriflora* Miq. | Fabaceae-Mim. | 30 | 20 | 24 | 92 | 0.452 | 0.403 | 0.097 | 0.129 | 0.065 | 0.000 | 0.000 | 0.000 | 0.339 | 1.484 |
| Murtinha | *Myrcia* spp. | Myrtaceae | 29 | 19 | 21 | 90 | 0.452 | 0.355 | 0.339 | 0.032 | 0.000 | 0.048 | 0.048 | 0.000 | 0.177 | 1.452 |
| Inajá | *Maximiliana maripa* (Aubl.) Drude | Arecaceae | 37 | 23 | 33 | 83 | 0.000 | 0.048 | 0.113 | 0.565 | 0.000 | 0.565 | 0.000 | 0.016 | 0.032 | 1.339 |
| Lacre-vermelho | *Vismia sandwithii* Ewan<br>*Vismia japurensis* Reichardt | Clusiaceae | 35 | 22 | 33 | 83 | 0.516 | 0.000 | 0.355 | 0.000 | 0.427 | 0.000 | 0.000 | 0.000 | 0.032 | 1.331 |
| Sucúba | *Himatanthus stenophyllus* Plumel<br>*Himatanthus sucuuba* (Spruce ex Müll. Arg.) Woodson | Apocynaceae | 27 | 20 | 23 | 80 | 0.323 | 0.000 | 0.048 | 0.000 | 0.903 | 0.000 | 0.000 | 0.000 | 0.016 | 1.290 |
| Muruxi | *Byrsonima crispa* A. Juss. | Malpighiaceae | 21 | 13 | 19 | 80 | 0.339 | 0.306 | 0.323 | 0.097 | 0.000 | 0.016 | 0.016 | 0.000 | 0.194 | 1.290 |
| Murumuru | *Astrocaryum murumuru* Mart. | Arecaceae | 35 | 35 | 9 | 79 | 0.000 | 0.113 | 0.000 | 0.129 | 0.000 | 0.419 | 0.000 | 0.516 | 0.097 | 1.274 |
| Ingá-cipó | *Inga longiflora* Spruce ex Benth.<br>*Inga* cf. *disticha* Benth.<br>*Inga* cf. *edulis* Mart. | Fabaceae-Mim. | 26 | 22 | 17 | 74 | 0.403 | 0.371 | 0.000 | 0.145 | 0.000 | 0.000 | 0.016 | 0.000 | 0.258 | 1.194 |
| Lacre-branco | *Vismia cayennensis* (Jacq.) Pers.<br>*Vismia gracilis* Hieron | Clusiaceae | 36 | 22 | 28 | 70 | 0.516 | 0.000 | 0.403 | 0.000 | 0.177 | 0.016 | 0.000 | 0.000 | 0.016 | 1.129 |
| Jacataca | *Lacmellea gracilis* (Müll. Arg.) Markgr. | Apocynaceae | 18 | 9 | 17 | 58 | 0.242 | 0.290 | 0.000 | 0.032 | 0.000 | 0.210 | 0.000 | 0.000 | 0.161 | 0.935 |
| Ingá-chato | *Inga macrophylla* Humb. & Bonpl. ex Willd. | Fabaceae-Mim. | 19 | 17 | 11 | 56 | 0.290 | 0.306 | 0.000 | 0.065 | 0.000 | 0.000 | 0.032 | 0.000 | 0.210 | 0.903 |
| Sapateiro | *Miconia* spp. | Melastomataceae | 25 | 12 | 24 | 54 | 0.371 | 0.016 | 0.290 | 0.032 | 0.000 | 0.016 | 0.032 | 0.000 | 0.113 | 0.871 |
| Cedrinho | *Cedrela* sp.<br>*Tapirira guianensis Aubl.* | Meliaceae<br>Anacardiaceae | 36 | 18 | 31 | 52 | 0.048 | 0.000 | 0.581 | 0.000 | 0.000 | 0.032 | 0.177 | 0.000 | 0.000 | 0.839 |
| Cachimbeira | *Casearia grandiflora* Cambess. | Celastraceae | 32 | 19 | 28 | 46 | 0.516 | 0.000 | 0.194 | 0.000 | 0.000 | 0.016 | 0.000 | 0.000 | 0.016 | 0.742 |

[a] Most likely botanical species to which the common name refers; [b] *Fabaceae-Mim.* refers to the subfamily Mimosoideae *sensu* APG II (2003); [c] ni = number of informants who cited the ethnospecies; [d] Number of informants who cited the ethnospecies on anthropogenic soils (TPI) and on non-anthropogenic soils (NAS); [e] Number of uses cited for the ethnospecies summed over all informants; [f] Use value of the ethnospecies in each of the use categories: fir = firewood, fod = food, cst = construction, hwt = hunting-wait tree, med = medicinal, tec = other technology, com = commerce/trade, han = house animals, oph = opportunistic hunting; [g] Total use value of the ethnospecies

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